

DANMARKS NATIONALBANK

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Danish mortgage bond liquidity briefly impacted by covid-19

Long term mortgage bond rates increased by approximately 0.70 percentage points over two weeks in March. A decrease in market liquidity was a significant contributory factor.

Mortgage rates are determined directly via the market. This means that mortgage rates may rise very quickly, but it also ensures that mortgage credit institutions can issue bonds and pay out mortgage loans even during periods of great uncertainty.

Weak demand put upward pressure on mortgage rates

The mortgage rate increases were primarily driven by weak demand for newly issued bonds and not by sales pressure from existing bond investors.

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Mortgage bond market remained open throughout period with market turmoil.

A number of the systemically important institutions, which are both issuers and market makers, were net buyers during the days with poorest liquidity.

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Mortgage credit institutions responsible for ensuring continuous market access

The mortgage credit institutions should use the experience from the covid-19 outbreak to assess whether the current setup is sufficiently robust.

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Decline in market liquidity resulted in increasing mortgage rates after covid-19 outbreak

The covid-19 outbreak in many Western countries caused great uncertainty about the economic outlook in March 2020. This uncertainty also affected the financial markets. On the Danish mortgage bond market, both rates and risk premiums soared briefly, concurrently with turmoil on a number of financial markets and pressure on the Danish krone.¹

Part of the risk premium increase may be due to a liquidity premium increase because of a brief period with a limited number of buyers of the bonds which the mortgage credit institutions needed to issue. This was particularly pronounced in weeks 11 and 12. At the end of week 12, a large number of central banks announced measures aimed at supporting the financial markets. This resulted in a decrease in the liquidity premium for Danish mortgage bonds.² Until the end of June 2020, the liquidity premium remained higher than in previous years.

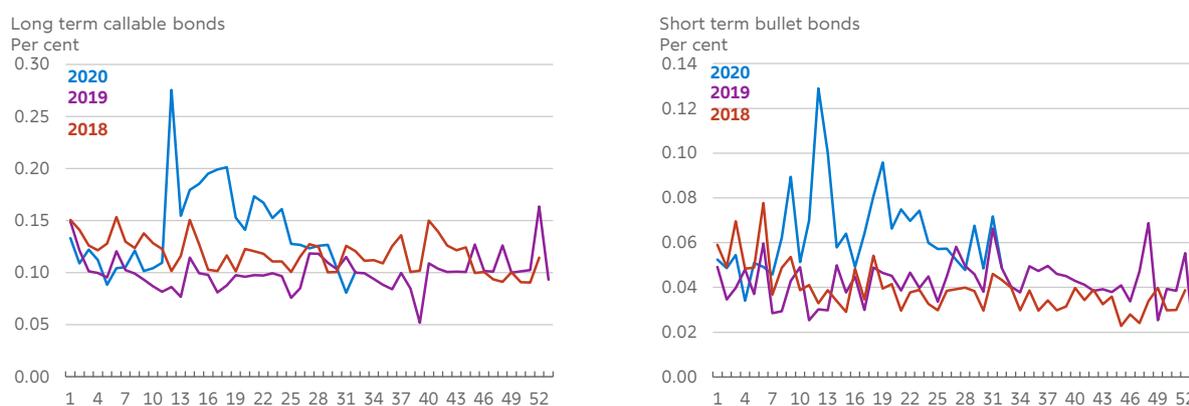
At its peak in March 2020, the liquidity premium was nearly twice as high as in 2015, when Danmarks Nationalbank examined the market liquidity prior to the implementation of the LCR rules and the MIFID II Directive.

The issuance of mortgage bonds continued in the weeks with market turmoil. In contrast, the issuance of covered bonds (corresponding to Danish mortgage bonds) was unusually low in other countries.

The analysis shows that demand for Danish mortgage bonds was low in mid-March, which was part of the reason for the increasing mortgage rates. In addition, the SIFIs, which are both market makers and mortgage issuers, were net buyers of mortgage bonds during the days with the weakest demand.

Liquidity costs were significantly above the normal level in mid-March 2020

Chart 1



Note: The charts show weekly liquidity premiums in 2018, 2019 and 2020. The left-hand chart shows the effect for long term callable bonds with more than 20 years to maturity. The right-hand chart shows the effect for the bonds underlying adjustable rate loans with a maturity of between one and five years. Very short-term instruments with a maturity of less than one year have been excluded because they are traded as money market instruments to a much higher degree than the other instruments.

Source: MIFID II reports and own calculations.

1 See Asger Munch Grønland and Lars Risbjerg, Pressure on the Danish krone in times of crisis, *Danmarks Nationalbank Economic Memo*, No. 11, 3 July 2020.

2 Used as a joint term for SDO, SDRO and RO.

What is a liquidity premium?

Box 1

In financial theory, the price of an asset (e.g. a bond) is explained by a risk-free element as well as a number of risk factors. The individual risk factors reflect the risk undertaken by investors when investing in the asset in question relative to a risk-free asset.

The share of the total price of the asset that is attributable to the specific risks is called risk premiums.

An unsecured loan to a customer with high debts and low earnings has a relatively high credit risk compared with a loan to, for example, the Danish Government. This will be reflected in a high interest rate to compensate for the higher credit risk. The part of the interest rate which can be attributed to paying for the credit risk is called the credit risk premium.

The most significant risks for Danish mortgage bonds are typically: credit risk, market risk, liquidity risk and option risk.

Liquidity risk reflects the uncertainty associated with how quickly the bonds can be sold and what the transaction costs will be. The liquidity premium reflects the additional interest that the investor will require in return for accepting the uncertainty.

On a market with many buyers, high turnover and good price transparency, an asset can typically be sold quickly and without significantly affecting the price. The liquidity premium will thus be low. C25 shares are examples of this.

However, there may be periods in which the discount that must be granted to sell an asset will increase quickly. This will result in an increasing liquidity premium.

Due to the mortgage bond market structure, mortgage rates will increase relatively quickly when investor demand is low. The reason is that the mortgage credit institutions need to issue new bonds continuously to finance their lending.³ The interest rate achieved in connection with bond sales is passed on directly to the borrowers, who bear the risk of interest rate fluctuations. The rapid interest rate changes contribute to the market quickly finding a new equilibrium, with investors again being willing to buy the issued bonds.

The development in March 2020 is an opportunity to look at whether the existing setup, including the existing market maker and primary dealer agreements, is sufficiently robust also to ensure the mortgage credit institutions' market access at times of turbulence. The mortgage credit institutions are responsible for ensuring that they can sell the necessary quantities at any given time.

Mortgage bond market liquidity is important to financial stability

The Danish mortgage bond market is often referred to as the world's largest market for covered bonds⁴, and mortgage bonds are an important element of the Danish financial sector as well as a significant factor in the transmission of monetary policy to the real economy. For example, mortgage bonds constitute around half of Danish banks' liquid reserves.⁵

A liquid mortgage bond market ensures that investors and banks assume limited liquidity risk when buying and holding mortgage bonds because they can sell them quickly and without a discount.

In order to maintain their lending activities, mortgage credit institutions need to be able to sell mortgage bonds on an ongoing basis, see Box 2. A robust and liquid mortgage bond market supports this.

³ Unlike conventional banks, mortgage credit institutions cannot finance their lending via deposits. Mortgage credit institutions solely finance their lending by issuing bonds, and they therefore have to accept the sales price they can obtain for the bonds. In return, the bond sales price is passed directly on to the borrowers.

⁴ See, for example, page 158 of ECBC European Covered Bond Fact Book 2019, ([link](#)).

⁵ See Danmarks Nationalbank, Financial Stability – Lower excess capital adequacy for the banks (Financial Stability 2nd Half 2019) *Danmarks Nationalbank Analysis*, No. 25, November 2019.

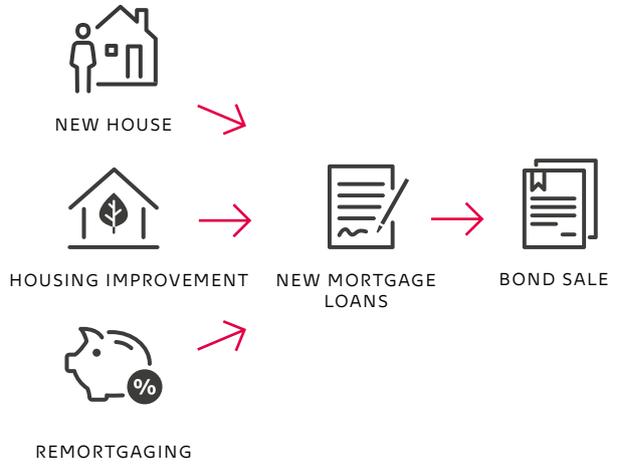
Mortgage credit institutions must sell bonds on an ongoing basis to support their lending

Box 2

Danish mortgage credit institutions are not allowed to receive deposits, and they therefore finance all their lending via bonds when borrowers want to take out new loans.

Mortgage credit institutions are also subject to the so-called balance principle, which means that they must continuously sell bonds to finance their disbursement of new loans or the conclusion of fixed-rate agreements.

This is in contrast to mortgage loan models in other countries, such as Sweden and Norway, where loans are not as closely linked to bonds as in Denmark. This means that issuers have more freedom to decide when to sell bonds, and consequently that the bond markets in these countries may be closed for shorter or longer periods without this necessarily impacting lending capacity.



Sales are made via tap auctions to market makers on the so-called primary market

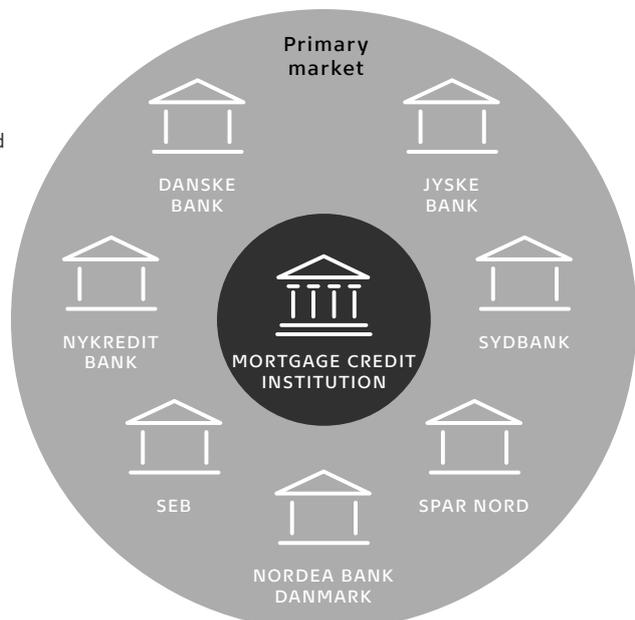
When Danish mortgage issuers need to sell bonds, this is typically done to a small group of banks, the so-called market makers. Sales from the mortgage credit institutions to these market makers are called the primary market and are made via a number of daily auctions (tap auctions), at which the mortgage credit institution sells the quantity which its lending business dictates, whereas the market makers determine the price by submitting bids in direct competition.

As a general rule, the market makers are not investors in the bonds and therefore depend on being able to resell the bonds to actual investors so as not to increase their market risks and capital adequacy requirements. The market makers generally earn the difference between the price they pay to the mortgage credit institution (bid) and their resale price (ask), the so-called bid-ask spread.

In times of financial turmoil, the market makers will typically increase the bid-ask spread to compensate for the increased

risk. In a worst-case scenario in which they are unable to resell the bonds, they may be forced to withdraw as buyers of the bonds from the mortgage credit institution, which, in such case, will have to find other ways of selling the bonds to maintain their lending activity.

The structure allows the market makers to pool the ongoing bond issues and sell them in larger quantities to investors on the so-called secondary market. The market makers can thus be supportive of liquidity during turbulent periods because the market makers can act as a short-term buffer and investor.



Financial turmoil in March also affected mortgage bonds

The financial markets were characterised by considerable turbulence in March as a result of the covid-19 outbreak. Volatility on the global equity, bond and foreign exchange markets was at its highest level for several years. Danish equity prices fell by approximately 25 per cent, and interest rates on Danish government bonds increased around 0.5-0.8 per cent.

Interest rates on Danish mortgage bonds, including both fixed-rate callable bonds and short term bullet bonds, increased by around 0.75-0.9 per cent in the course of two weeks following the global outbreak of the covid-19 pandemic, see Chart 2.

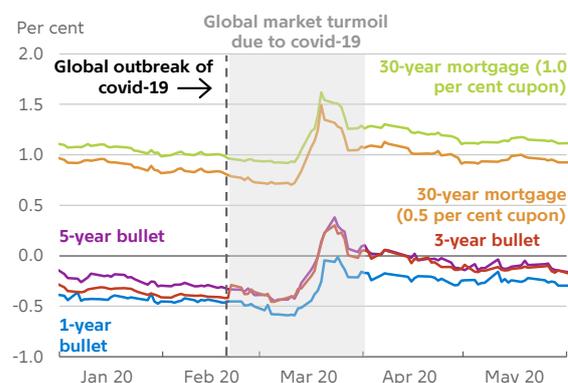
Market liquidity in Danish mortgage bonds is affected by a number of factors, including the liquidity development on the Danish money market. The reason is that large domestic buyers of Danish mortgage bonds use the money market to manage their day-to-day liquidity, and that especially short term Danish mortgage bonds are traded as substitutes for other money-market instruments, see Box 3.

Short-term money market interest rates, defined as 1-month CITA interest rate swap, increased by approximately 0.25 per cent during the financial turmoil in March. The increase partly reflected Danmarks Nationalbank's 0.15 per cent CD rate increase. The rest of the increase was due to the banking sector going from a situation with ample Danish krone liquidity to a situation in which some banks had a demand for liquidity on the money market.⁶

The rapid increase in interest rates on the money market, combined with declining Danish krone liquidity, may have impacted on the demand for short-term mortgage bonds. Firstly, the increase in interest rates results in a mark to market loss for existing investors and, secondly, lower Danish krone liquidity reduces the need to invest funds.

The outbreak of covid-19 led to higher mortgage rates

Chart 2



Note: Yields to maturity.
 Source: Refinitiv Eikon.

Liquidity costs increased significantly in mid-March 2020

Market liquidity on the mortgage bond market was unusually low in mid-March. This is evident regardless of whether the development in risk premiums (OAS), bid-ask spreads or the price effect from observed trades are used as measures of market liquidity.

Increase in risk premiums contributed to rising mortgage rates in March

The covid-19 outbreak resulted in a very quick and short-term increase in the option-adjusted spread (OAS). This is an indication of high uncertainty and of the liquidity premium being the main driver, see Box 4. The same sort of pressure on market liquidity was seen during the financial crisis, for example, see Chart 4.

⁶ See Danmarks Nationalbank, *Stabilisation of financial markets after covid-19 turmoil (Monetary and financial trends)*, Danmarks Nationalbank Analysis, June 2020.

Difference between investor groups in long and short term bonds

Box 3

The Danish mortgage bond market is often referred to as a single market. However, on the investor side, where the market liquidity is created, it is important to distinguish between the different bond types, as they typically attract very different investor groups, which has implications for liquidity.

It is particularly important to consider the difference between short and long term bonds.

In Denmark, fixed-rate loans are financed with bonds with a maturity of up to 33 years, fixed interest rate and an option for early redemption. The option means that the expected cash flow for investors is unknown. In turn, variable-rate loans are financed by shorter bonds, typically with a maturity of up to five years and with a known cash flow.¹

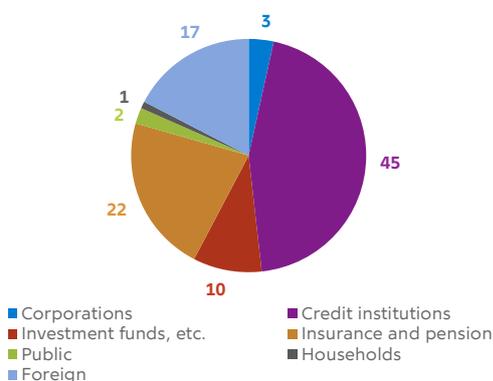
Due to the considerable differences between the bonds, they attract very different groups of investors, see Chart 3. For example, banks and mortgage credit institutions constitute 45 per cent of investors in the short term bond segment, but only 6 per cent of investors in long term bonds. Short term bonds are typically used as part of the banks' liquidity reserve, and a known cash flow and a short term to maturity are important features here.

In long term bonds, foreign investors, insurance companies and pension funds as well as the group comprising asset managers and investment funds constitute by far the biggest share of investors. These are typically long-term investors, which can undertake the higher market risk associated with long bonds.

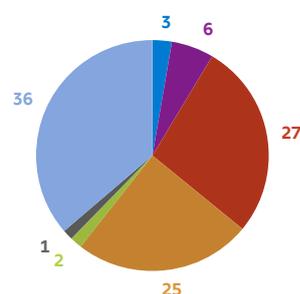
Considerable difference in investor breakdown between short and long term mortgage bonds

Chart 3

Short term bonds, per cent



Long term bonds, per cent



Source: Danmarks Nationalbank.

1. This is a simplified description of the market. For example, it also includes variable-rate bonds with hybrid amortisation, where the cash flow is not fully known. However, these bonds still have risk characteristics that are more similar to short term bullet bonds and attract a similar group of investors. See, for example, Nykredit: Danish covered bonds 2020/2021 for a complete description of the individual bond types: [\(link\)](#).

Sudden OAS increase reminiscent of situation during financial crisis

Chart 4



Source: Nykredit Realkreditindex (Mortgage Index) and own presentation.

The option-adjusted spread (OAS) is generally low for Danish mortgage bonds, reflecting the fact that credit and liquidity premiums are generally low. However, significant OAS increases may occur during short periods of financial turmoil.

OAS increases may be an indicator of reduced market liquidity, but it is not an exact measure, as OAS also reflects changes in other risk factors. For example, the OAS increase in 2015 was not associated with any market liquidity challenges. Instead, the increase occurred more gradually over an extended period, indicating that credit risk was a more significant driver than liquidity risk.

In March, the days on which the Danish krone liquidity in the Danish banking sector began to decrease were also the days on which significant OAS increases were seen across both bond types and maturities, see Chart 5. This further indicates that rising liquidity premiums contributed to the increase in mortgage rates in mid-March.

Liquidity premium peaked in week 12

The price change between two trades is a more direct liquidity premium measure than OAS. On a market with frequent trading, credit risk can be assumed to play a marginal role in price fluctuations between two trades, and the relative price change

The option-adjusted spread as a measure of market liquidity

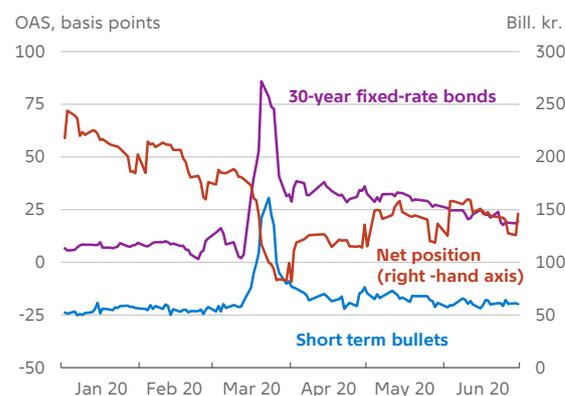
Box 4

The option-adjusted spread (OAS) reflects the additional return an investor requires for buying the expected cash flow of a mortgage bond as opposed to holding a portfolio of short interest rates. In other words, OAS is defined by the yield to maturity less the underlying interest rate and the value of the prepayment option, see Appendix 2.

The underlying interest rate is based on zero coupon rates constructed via CIBOR swap rates. The use of CIBOR swap rates as an interest rate structure means that OAS is a measure of the size of liquidity and credit premiums in excess of what is reflected in the CIBOR swap curve. As the CIBOR swap curve contains credit risk related to interbank payments, OAS cannot be interpreted as the full size of the risk premiums for mortgage bonds. Instead, it must be interpreted as the size of risk premiums in excess of the CIBOR swap curve. However, it gives a picture of whether the mortgage risk premiums are increasing/decreasing by more than the risk premiums on the interbank market. An OAS increase may therefore be an indicator of an increasing mortgage bond liquidity premium.

OAS increases in March affected several bond types

Chart 5



Note: Weighted average of option-adjusted spreads across bond types and maturities. RTLs cover maturities of 1-5 years. The net position refers to the total net balance of monetary policy counterparties in Danish kroner with Danmarks Nationalbank.

Source: Scanrate RIO, Danmarks Nationalbank and own calculations.

can therefore be used as a measure of the liquidity premium.⁷

In March 2020, the liquidity premium, as measured by the price impact of observed trades, peaked in week 12, see Chart 6. Based on daily observations, Monday, 16 March and Thursday, 19 March had the highest liquidity premia.

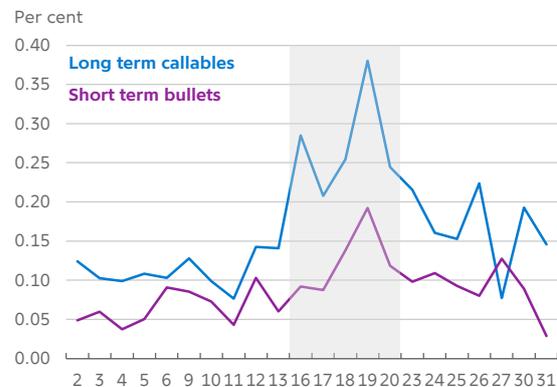
Monday, 16 March was the first trading day after the Danish lockdown, which meant, for example, that schools and kindergartens were closed. Many of the market players had been sent home, which may have increased transaction costs for operational reasons. Furthermore, at the end of week 11 uncertainty grew about how the situation would develop. The equity market had dropped by 17 per cent in week 11 (the sharpest weekly decrease in the period), and, towards the end of the week, the Danish Minister for Industry, Business and Financial Affairs announced the release of the countercyclical buffer.⁸

The main fluctuations on the mortgage bond market occurred during week 12, when the risk premium for long term bonds increased by approximately 70 basis points, see Chart 5. Towards the end of week 12, a number of initiatives were announced by central banks and supervisory authorities, both internationally and in Denmark⁹, and the mortgage credit market gradually stabilised from week 13 onwards.

The decrease in market liquidity on March 16 occurred primarily in long term callable bonds, while short term bonds were not affected until later in the week. The liquidity premium increased in both bond types with a factor of nearly 4 relative to the beginning of March.

Liquidity premium increased in week 12

Chart 6



Note: Daily development in liquidity premiums for March 2020. Week 12 is marked in grey.
 Source: MIFID II reports and own calculations.

The significant and rapid increase in the liquidity premium confirms the picture that the interest rate increases seen on the mortgage credit market were largely driven by decreasing market liquidity.

Bid-ask spread also increased significantly during the market turmoil in March

The third measure of market liquidity is the bid-ask spread, which measure the difference between the bid and ask prices set by market makers. The bid-ask spread for long term mortgage bonds increased by approximately kr. 0.30 to approximately kr. 0.60, see Chart 7.¹⁰ However, the bid-ask spread for short term mortgage bonds remained largely unchanged. A similar development was seen under the financial crisis in 2008, see Buchholst et al. (2010).¹¹

⁷ See Appendix 3 for method description.

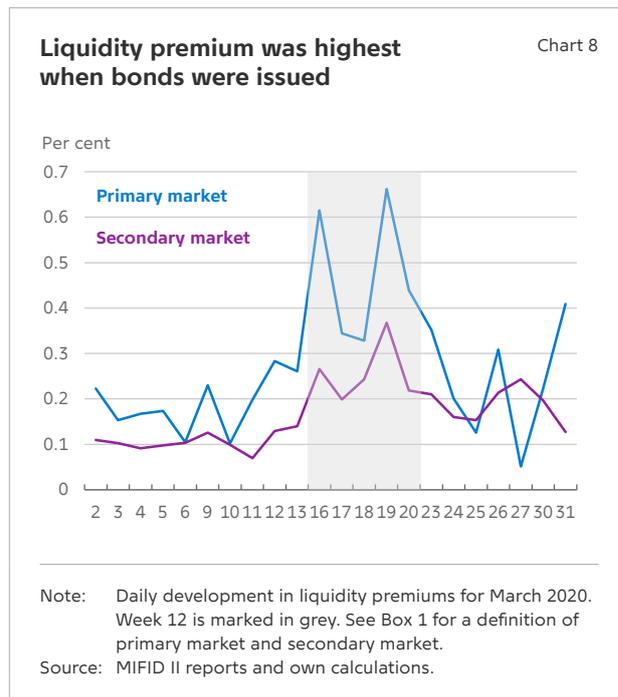
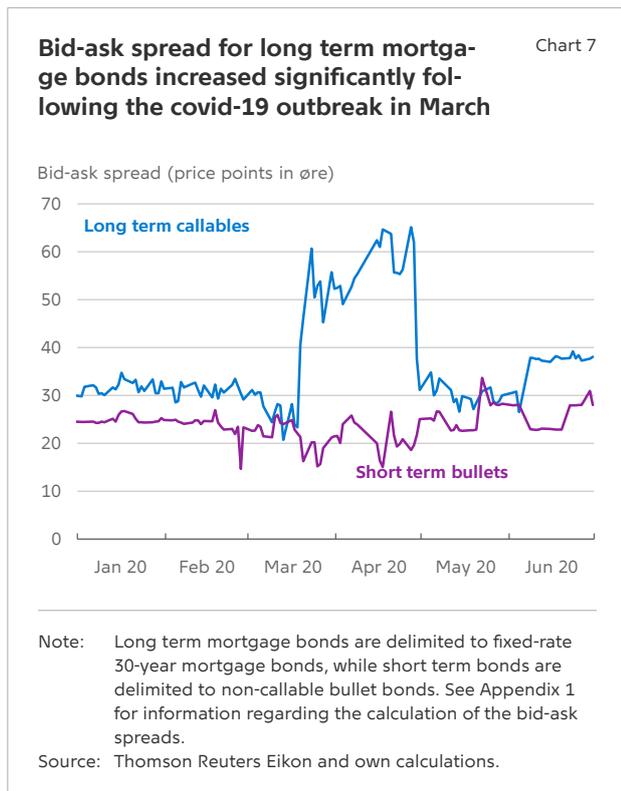
⁸ See (link).

⁹ In the afternoon on 19 March, Danmarks Nationalbank announced that swap lines had been set up with both the FED and the ECB to ensure access for Danish banks to USD and EUR. The opening of a three-month lending facility concurrently with an interest rate increase was also announced.

On the same day, the Danish Financial Supervisory Authority announced that banks could apply for permission to disregard the so-called unwind rule when calculating their liquidity coverage ratio (LCR). On 18 March, the ECB announced an EUR 750 billion asset purchase programme, and, on 20 March, the ECB announced a coordinated action with a number of major international central banks to enhance the provision of USD liquidity.

¹⁰ See Appendix 1 for method description.

¹¹ By comparison, the bid-ask spread for Danish government bonds increased by approximately 15 basis points in connection with the start of the covid-19 crisis in the two weeks following the lockdown of Danish society. See Danmarks Nationalbank (2020), Stabilisation of financial markets after covid-19 turmoil (Monetary and financial trends), Danmarks Nationalbank Analysis, No. 11, June 2020.



The liquidity premium was higher for issuance than for resales

The market liquidity on the primary and secondary markets developed differently during the period. This was particularly the case in week 12¹², where the liquidity premium for long bonds was significantly higher on the primary market than on the secondary market, see Chart 8. This suggests that the mortgage credit institutions' ongoing issuance of bonds put particular pressure on mortgage bond prices on those days.¹³

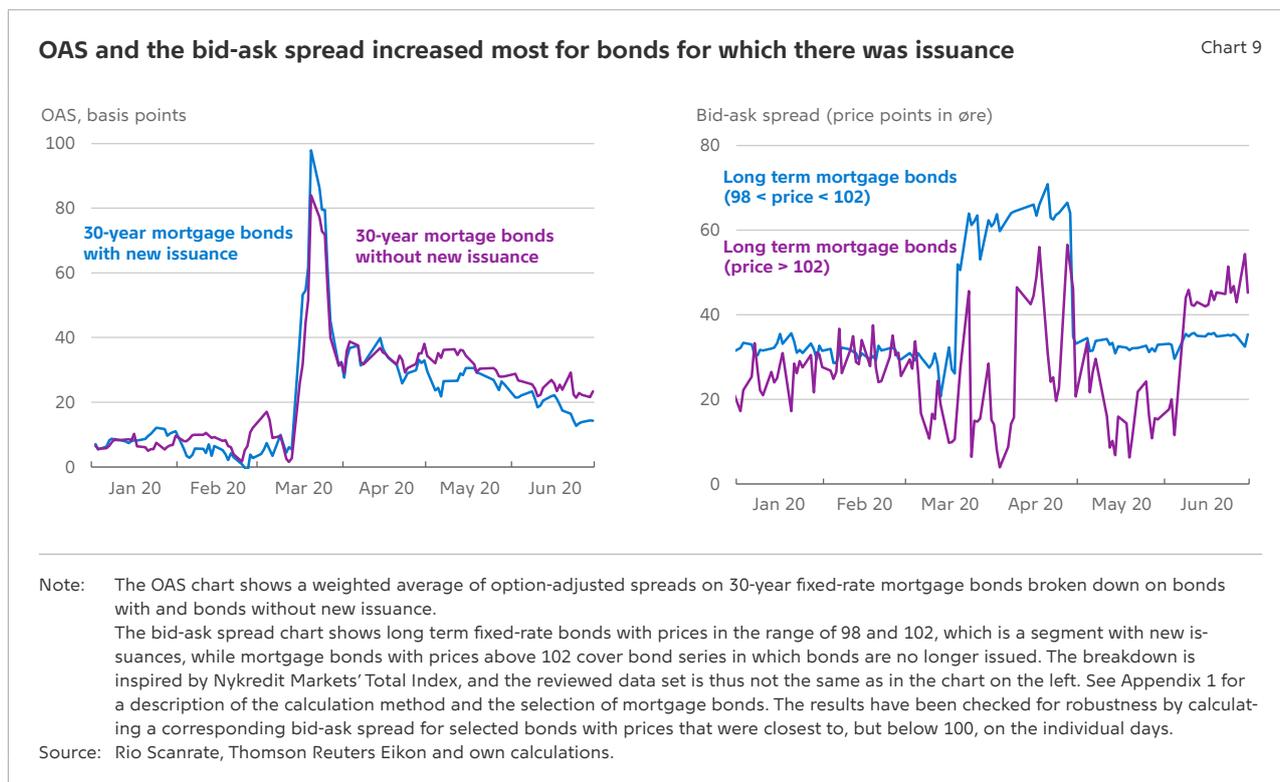
The same picture can be seen when looking at the bid-ask spread and OAS, where the liquidity premi-

um seems to be higher for the segments of bonds with new issuances during the period, see Chart 9.

During the most turbulent days in March, the market makers thus requested a higher payment for the liquidity risk than the mortgage bond market as a whole. This is not surprising considering that trading on the primary market is more supply-driven than on the rest of the market, and that, on a turbulent market, the market makers run a significant risk related to whether they will be able to resell the bonds, see Box 2.

12 On many financial markets, the liquidity on the last day of the quarter is generally different to other times of the year, and the observation on 31 March therefore provides an uncertain basis of comparison.

13 It should be recalled that the liquidity effect is measured from trade to trade and is calculated as a median, while the marginal effect of each trade is the price-driving factor. The higher value on the primary market thus affects prices more than the further trading on the secondary market.



The difference in market liquidity between bonds open for issuance and bonds closed for issuance contributes to supporting the hypothesis that the price decreases in connection with the covid-19 crisis were largely due to a lack of demand for ongoing issuances rather than a general sales pressure on Danish mortgage bonds.

For short term bonds, the primary market did not tend to have a significantly higher liquidity premium than the secondary market.

Prices fell when new bonds were issued

Because the primary market is driven by supply¹⁴, price change developments can be used to interpret how the market makers acted.¹⁵

During the days with the most intense liquidity pressure, new issuances resulted in a significantly

negative price change, see Chart 10.¹⁶ This indicates that there was no great interest in buying the mortgage credit institutions' bonds when they were offered for sale and the market makers therefore reduced the prices markedly when the mortgage bond issuers entered the market to sell bonds.

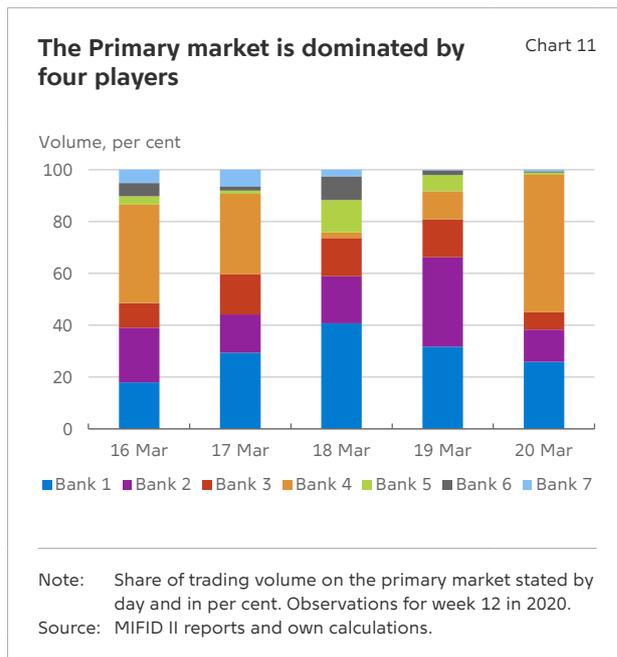
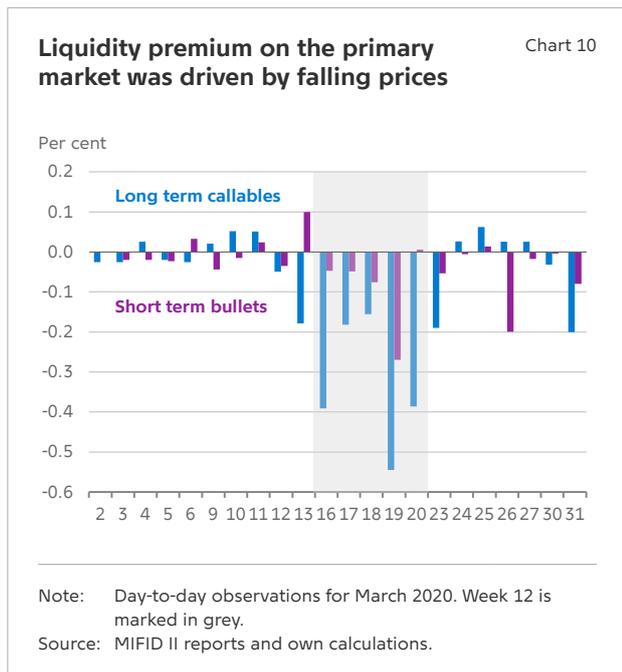
Did all the market makers actually contribute to market liquidity?

The primary mortgage bond market is characterised by a limited number of market makers, which means that the behaviour of individual players can have a relatively strong impact on market liquidity.

¹⁴ See Box 2.

¹⁵ On the primary market, the mortgage credit institutions decide the volume, while the market makers decide the price. The price therefore reflects the market makers' bid price.

¹⁶ A similar calculation for the secondary market shows an effect close to 0 except for the days with the greatest pressure, on which the effect was slightly negative for long bonds (-0.05 per cent on 19 March). This is also as expected, seeing that prices on the secondary market must be expected to fluctuate between purchases and sales to a much higher degree.

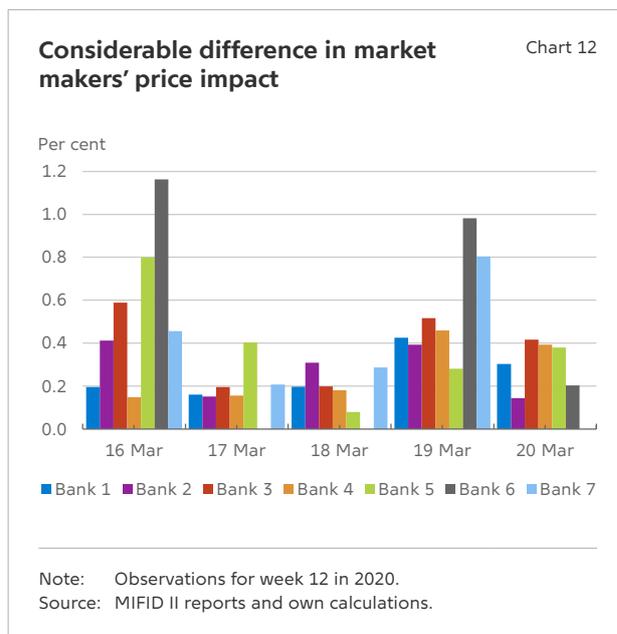


In week 12, trading was highly concentrated on four market makers, but with differences on the individual days, see Chart 11. One of the biggest players appears to have withdrawn from the market on Wednesday, 18 March.

Chart 12 shows the price impact broken down on market makers on the primary market. It gives a picture of which of the market makers demanded the largest price change in order to buy bonds from the mortgage credit institutions.¹⁷

Comparing Charts 11 and 12 shows that the market makers who bought the largest volumes also had the most stable price impact. For example, the price impact of bank 1 and bank 4 is below 0.2 per cent up to and including Wednesday. After that, the price impact seems to have increased to a new level on Thursday and Friday.

The fact that the banks with the highest trading volumes also have the most stable prices indicates that these banks have a stabilising effect on the market.



¹⁷ It is worth noting that the chart does not give the full picture of each market maker's behaviour, as it only covers concluded trades. A full picture will require looking at the full bid history of each market maker, and we do not have access to such data.

In addition, the individual market maker banks' total net purchases and sales in weeks 11, 12 and 13 shows that there were few net buyers, and that they were primarily found in the SIFI groups. This indicates that some of the SIFI players had a more stabilising role on the mortgage credit market than others during the most turbulent period.

Account should be taken of the fact that several of the market makers are also part of financial groups that include a mortgage credit institution, and that all market maker banks are also expectedly mortgage bond investors. There may consequently be other considerations underlying purchases/sales of mortgage bonds than what can immediately be expected based on a narrow focus on the market makers' business model.

Market maker schemes on the Danish mortgage credit market

Box 5

There are two different market maker schemes on the Danish mortgage credit market, and these schemes are run by the Danish Securities Dealers Association/Finance Denmark. Both schemes are connected to the secondary market. Under these schemes, the market makers are obliged to quote two-way prices to each other in connection with requests for quote. However, the market makers typically also quote prices for bonds that are not covered by any schemes. The purpose of both schemes is to support market liquidity and ensure effective price formation.

One market maker scheme is a price quotation scheme for long term mortgage bonds, while the other market maker scheme comprises bonds with maturities of up to 13 months.

The following seven banks participate in the market maker schemes: Danske Bank, Jyske Bank, Nordea Denmark, Nykredit Bank, Sydbank, Spar Nord and SEB. The schemes oblige the market makers to be present on the market with agreed amounts, in order to contribute to ensuring that investors can always trade mortgage bonds at a reasonable price and without an excessive market impact.

In addition, the mortgage credit institutions have themselves entered into individual market maker agreements (so-called primary dealer agreements) with relevant banks to support the liquidity of their own bonds.

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Calculation of bid-ask spreads for Danish mortgage bonds

Appendix 1

The bid-ask spread is calculated on the basis of indicative prices quoted on an hourly basis by Danske Bank, Jyske Bank, Nordea Danmark and Nykredit Markets, and the data has been collected via Thomson Reuters Eikon. All four institutions are members of the Danish Securities Dealers Association's market maker scheme, and the market makers have been selected on the basis of the frequency of quoted prices and their market share.

The bid-ask spread is calculated as the difference between the best bid and ask (the highest quoted purchase price and the lowest quoted sales price) for a selection of mortgage bonds with an outstanding volume in excess of kr. 5 billion. All bonds are issued in Danish kroner and by the mortgage credit institutions DLR Kredit, Jyske Realkredit, Nordea Kredit, Nykredit Realkredit and Realkredit Danmark. Selecting the highest quoted purchase price and the lowest quoted sales price and calculating the spread as the difference between them gives an effective bid-ask spread, which only includes the sharpest prices on both sides of the spread. The spread is calculated as a weighted average based on the outstanding volumes. The observations are calculated as the average between the hours of 10-16 on trading days, when most trades are made.

In the calculation of the bid-ask spreads, a distinction is made between long and short term mortgage bonds and between fixed-rate and variable-rate yields on the under-

lying mortgage loans. In specific terms, a division of the bid-ask spreads is made using the following criteria. The first bid-ask spread is calculated for fixed-rate mortgage bonds with a maturity of 30 years, and where bond prices are in the range of 98 to 102 (on-the-run, long). The breakdown is inspired by Nykredit's Total Index, in which bonds with prices in this range include bonds which are typically open mortgage bond series with the highest issuance activity. When the bonds are traded close to price 100, the conversion option strike price is close to the market price and with a concurrent relatively high fluctuation in duration. The bid-ask spread is subsequently calculated for fixed-rate mortgage bonds with a maturity of 30 years and with a price above 102 (off-the-run, long). The division includes a specialised segment dominated by many small mortgage bond series with low turnover characterised by small trades. The last segment comprises short-term mortgage bonds with a short maturity and with variable yield (RTL). The division is made to be able to take into account for differences in duration between the bonds, among other factors. See the below table for an overview of the selected bonds.

The selected bonds are traded on Nasdaq Copenhagen, and the information about the trades is also published there. This forms part of a voluntary industry agreement in Denmark that ensures high post-trade transparency.

Bonds used to calculate the bid-ask spreads

On-the-run, long	Off-the-run, long	RTL
1 DLR B MTG 2050 IO	1.5 JYK E MTG 2050	1 RD T RTL 2022
1 NYK E MTG 2050 IO	2 NYK E MTG 2050	1 JYK E RTL 2022
1 NDA 2 MTG 2050 IO	1.5 RD S MTG 2050	1 NDA 2 RTL 2022
1 RD S MTG 2050	2 NDA 2 MTG 2050	1 NDA 2 RTL 2023
1 JYK E MTG 2050 IO	1.5 NDA 2 MTG 2050	1 JYK E RTL 2023
1 NYK E MTG 2050	1.5 NYK E MTG 2050	1 RD T RTL 2023
1 JYK E MTG 2050	2 RD S MTG 2050	1 RD T RTL 2024
1 NDA 2 MTG 2050		1 NDA 2 RTL 2024
1 RD S MTG 2050 IO		1 JYK E RTL 2024
1 DLR B MTG 2050		

Note: *On-the-run, long* indicates long term fixed-rate mortgage bonds with prices in the range of 98 to 102. *Off-the-run, long* indicates long term fixed-rate mortgage bonds with prices above 102. *RTL* are short term bullet bonds which are referred to in the analysis as mortgage bonds with short maturity. The cut-off points are inspired by Nykredit's Total Index.

Source: Scanrate RIO and Danmarks Nationalbank.

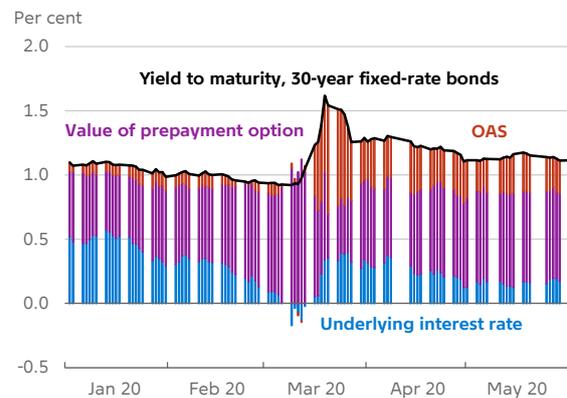
Decomposition of mortgage rates and value of the prepayment option

Appendix 2

In practice, the value of the prepayment option is calculated using complex models for early redemptions. Here, an existing model developed by Scanrate is used. The level of the value of the prepayment option depends on the type of bond. For a bond with a long maturity, the value is high, as an investor will miss several interest payments in the event of early redemption. To illustrate how the prepayment option affects the market interest rate, a decomposition of a long term fixed-rate mortgage (30-year, 1 per cent coupon) is considered, see Chart A. The bond is callable and contains an option with a strike value of 100, see above.

In general the value depends on the investors' assessment of the risk that households will repay their loans. One significant parameter is the bond coupon rate relative to the general interest rate level. If the general interest rate level increases relative to the coupon rate, the risk of early prepayment decreases, which means that the value of the prepayment option also decreases (i.e. investors require lower additional payment). This was, for example, the case during the market turmoil in March and therefore explains why the value of the prepayment option fell in line with the increase in interest rates. The value of the prepayment option also depends on other parameters, including expected interest rate volatility, which typically plays a major role during substantial market turmoil. The expected volatility increased significantly during the market turmoil in March, contributing to the increase in mortgage rates. Expected volatility may have been priced in via OAS. This is because OAS depends on the volatility of the underlying price formation model. OAS may therefore take account of factors other than market risk premiums. The reason for this is that OAS is calculated residually via the difference between the theoretical price and the observed market price.

A: Decomposition of market interest rates on long term fixed-rate mortgage bond



Note: Decomposition of yield to maturity of a 30-year fixed-rate mortgage bond with a coupon rate of 1 per cent. The underlying interest rate structure is based on CIBOR swap rates.

Source: Scanrate, Refinitiv Eikon and own calculations.

1. The value of the right to redeem a loan at par also depends on other factors, for example expected interest rate volatility.
2. The interest rate for the older mortgage bond in Chart A was the current market rate from July 2012 – September 2012 and therefore has the same interest rate as the marginal loan cost during that period.

Estimation of liquidity premium via transaction data

Appendix 3

The analysis of observed liquidity premiums is based on detailed information about mortgage bond market trades from the MIFID II reports. The transaction reports contain information about the size, price and time of all Danish mortgage bond trades. In the dataset, the bonds are identified with unique ISIN codes, making it possible to add the bond master data as well as additional relevant information such as outstanding volume and remaining

term to maturity from Danmarks Nationalbank's Securities Statistics.

Processing of data

The MIFID transaction reports are generally a supervisory tool used by the Danish Financial Supervisory Authority. To adjust the data basis to the purpose of the analysis, a number of filtrations have been made.

Filter	Background
Repo transactions are excluded	Det used dataset doesn't include repo transactions
Double counting is excluded	Transactions between reporters are reported by both sides of the trade
Transactions without information in Danmarks Nationalbank's Securities Statistics are excluded	Information from Danmarks Nationalbank's Securities Statistics is necessary to classify the bonds.
Error reporting is excluded	Transactions for which at least one of the following conditions apply are assessed to be incorrect: <ul style="list-style-type: none"> - Trade price is lower than 50 or higher than 160 - Trade price deviates by at least 5 price points from the previous traded price - The nominal value of the transaction is higher than the total volume issued - Trade size is above 500 mio. Danske kroner, which is the largest trade size possible pr. trade at NasdaqOMX
Transactions below 10 mio. Dansk kroner is excluded	The analysis focuses on the transactions of institutional investors. Consequently the large number of small retail transactions made in connection with individual mortgage loans are excluded
Trade with same buyer and seller is excluded	Trades with same buyer and seller are assessed to be internal trades, which doesn't necessarily reflect the market liquidity
Trades in other currencies than Dansk kroner	The analysis focusses on trades in Danish kroner

Calculation of price impact in connection with trades

The price impact in connection with a trade is calculated as the numerical percentage change in the trading price (P) for bond (k) on day (t) for two consecutive trades (i) and ($i-1$).

$$Price\ impact_{k,t,i} = \frac{|P_{k,t,i} - P_{k,t,i-1}|}{P_{k,t,i-1}} \times 100$$

In some studies, the price impact is adjusted for trading volume. However, several previous studies based on Danish data have not found a significant correlation between price impact and trading volume¹. As a robustness test, the calculations on which the analysis is based are performed inclusive of a correction for trading volume, and the results correspond. It has therefore been decided not to correct for trading volume to be able to interpret the price impact more unambiguously relative to the other measures used in the analysis.

To make it less likely that prices between two trades change for reasons other than the price impact of the trade, for example the publication of new information to the market,

only price impacts from same-day trades are included. Also, trades for which the price impact is zero have been left out.

After calculating the price impact measure, the median observation per bond and per time period is used.

In part of the analysis, the price impact measure is also marked with a positive or negative sign. In this case, the price impacts are listed in ascending order and based on the median.

Definition of primary market and secondary market

The primary market has been defined as: All trades where a mortgage credit institution is listed as the seller and where the buyer is one of the following banks: Danske Bank, Jyske Bank, Nordea Denmark, Nykredit Bank, Sydbank, Spar Nord and SEB.

The secondary market is defined as all trades where one of the mortgage credit institutions is not listed as the seller.

1. Analyses in both Dick-Nielsen, Gyntelberg and Sangill (2012), Dick-Nielsen, Gyntelberg and Lund (2014) as well as Dick-Nielsen and Gyntelberg (2020) find that the price impact on the mortgage credit market is approximately the same for different trading volumes.

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WORKING PAPER

Working Paper presents research projects by economists in Danmarks Nationalbank and their associates. The series is primarily targeted at professionals and people with an interest for academia. Working Paper is published continuously.

The analysis consists of a Danish and an English version. In case of doubt regarding the correctness of the translation the Danish version is considered to be binding.

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